No Evidence for a Role of Reconsolidation in Updating of Paired Associates

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Brief Article

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Abstract

Reconsolidation theory states that memories are labilized through reactivation, making them prone to change, before being re-consolidated. When information in memory requires updating, reconsolidation theory therefore predicts that reminders of previously learned information should facilitate updating of that information and should thus improve memory for the updated information. In two experiments, we tested this prediction by investigating memory for word pairs over a short time-scale. Participants studied word pairs (A-B), some of which were subsequently updated with word pairs that shared the first word (A-C). Half of the A-C pairs received a pre-study reminder of the first word in the pair so as to reactivate and labilize A-B memory. In a recognition memory test targeting the A-C list, reminders by and large had no effect on memory. Results thus failed to support the predictions of reconsolidation theory.

Keywords: Memory updating; Paired-associate learning; Recognition memory; Reconsolidation; Interference

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A prime function of any memory system is to maintain stable representations of information. However, the fact that the world constantly changes requires that memory also be flexible, as its contents frequently need to be updated to remain accurate. It has been argued that this distinction between memory stability and flexibility is reflected in two proposed neural processes relevant for human memory: consolidation and reconsolidation. Consolidation is a presumed post-encoding process thought to stabilize memory traces in order to make them relatively permanent and resistant to disruption and forgetting (for a review, see Wixted, 2004). Yet, to account for people's ability to flexibly update memory, reconsolidation theory proposes that even consolidated memories are amenable to change. The idea is that reactivating a memory, typically by way of retrieval, destabilizes the trace. This so-called labilization process then facilitates updating, after which labilized memory traces are *re*consolidated to again achieve stability (Hupbach, Gomez, Hardt, & Nadel, 2007; Lee, 2009; St. Jacques, Montgomery, & Schacter, 2015; see Agren, 2014, for a review).

The most convincing evidence for reconsolidation comes from the literature on conditioning in animals. For example, in a study on fear-conditioned rats, Nader and Hardt (2009) utilized a 'reminder' paradigm: After conditioning, the animals were reminded of the conditioned stimulus (i.e., they were re-exposed to the conditioned stimulus so as to elicit the conditioned response) in order to labilize the memory trace. Animals that were then immediately treated with an amnestic agent (i.e., electroconvulsive shock or a protein synthesis inhibitor) showed an extinguished response to the conditioned stimulus on later presentation. Likewise, research into reconsolidation in humans has often used reminders of initially learned material to labilize memories, and the learning of a second stimulus as an "amnestic agent" to interrupt the reconsolidation of the labilized memory trace. Such reconsolidation effects have been established mainly in human procedural memory (e.g., Walker, Brakefield, Hobson, & Stickgold, 2003; but see Hardwicke, Mahdi, & Shanks, 2016, for a replication failure).

Several studies have aimed to demonstrate reconsolidation in human declarative memory, but results have been mixed and inconclusive. Hupbach and colleagues (e.g., Hupbach et al., 2007) had participants learn a set of items that were each produced from a blue basket (set 1). Half the participants were then given a reminder of set 1 (by being shown the blue basket) before learning a second set of items (set 2). It was found that a reminder led to more intrusion errors, with set-2 items intruding into recall of set 1, but not vice versa. This asymmetric intrusion pattern was taken as evidence for reconsolidation in human episodic memory.

However, Sederberg, Gershman, Polyn, and Norman (2011) showed that this asymmetric pattern of errors can be explained by item-context binding and contextual reinstatement. Sederberg et al. argued that the temporal context in which something is experienced is bound to its memory trace, and can then be used as a retrieval cue. If the reminder in Hupbach et al.'s (2007) studies reinstated set-1 context, and set-2 memory traces were then bound to both the set-2 context as well as the reinstated set-1 context, then using set-1 context as a retrieval cue (i.e., asking people to recall set 1) would lead to the retrieval of both set-1 and set-2 items—which could explain the intrusion asymmetry without recourse to a reconsolidation mechanism.

Chan and LaPaglia (2013) investigated reconsolidation effects in the post-event misinformation paradigm. They presented participants with a movie, and then one or two days later participants recalled the movie in a reactivation condition or engaged in distractor activity (no reactivation), before receiving a narrative misrepresenting some of the movie details. Subsequent memory for the original movie details was impaired in the reactivation condition relative to the no-reactivation control. This study must thus be seen as the perhaps strongest available piece of evidence for reconsolidation in human episodic memory.

Somewhat relatedly, Ecker, Hogan, and Lewandowsky (in press) investigated the effects of reminders in the continued-influence misinformation paradigm. In this paradigm, an initial piece of misinformation is corrected within a few minutes of its initial encoding. Ecker et al. found that correction of initially processed false information was facilitated, not compromised, if the correction repeated the false information (also see Wilkes and Leatherbarrow, 1988, for a similar effect; and Pashler, Kang, & Mozer, 2013, for an equivalent effect on a longer time scale).

Other neat demonstration of reactivation-related updating were reported by St. Jacques and colleagues (e.g., St. Jacques et al., 2015). In this study, participants went on a museum tour, and later specific memories for stops of the tour were reactivated via photographs. On some trials, the reminder photographs were followed by lure photographs from a different tour. St. Jacques et al. (2015) reported reminders to not only lead to improved memory for reactivated targets, but also more false memories for post-reminder lures relative to baseline targets and lures, respectively. This could be taken as evidence for reconsolidation; however, it is noteworthy that in this study, the additional post-reminder encoding of the lure led to *improved* memory for the reactivated target rather than the disruption seen in conditioning studies and the study of Chan and LaPaglia (2013). The evidence for reconsolidation in human episodic memory thus remains inconclusive.

Like the Hupbach et al. (2007) studies, most reconsolidation experiments have investigated the disruption of reactivated memory traces. The current study is more in line with the studies by St. Jacques and colleagues (e.g., St. Jacques et al., 2015) as it aims to focus on the memory updating aspect of reconsolidation: Labilizing a memory trace should not only allow for its distortion or disruption, but should also facilitate intentional changes, that is, memory updating. Memory updating involves modification of a memory trace to include new input (e.g., Ecker, Lewandowsky, Oberauer, & Chee, 2010). It is important as an adaptive function to keep memory traces current and relevant, as memories are often retrieved in environments that supply new information to be integrated into the retrieved memory (Lee, 2009; Wilkes & Leatherbarrow, 1988).

As discussed above, reconsolidation theory proposes that reactivation, labilization, and reconsolidation processes together comprise an updating mechanism (Lee, 2009; St. Jacques et al., 2015). Thus, reconsolidation theory makes strong predictions about the use of reactivating reminders in a paradigm involving memory updating: reminders of to-be-updated information should facilitate its updating and thus improve memory for the updated information. The current study aimed to test this prediction using an associative recognition paradigm involving the study of word pairs. If a word pair (A-B) is studied and later reactivated by a reminder (A), then this reactivation should facilitate updating of A-B. Thus, if an updated word pair (A-C) is provided, the substitution of the associate word (replace B with C) should be facilitated by the reminder, improving memory for A-C. Thus, this study aimed to test the relevance of reconsolidation for memory updating on a short time-scale (i.e., minutes; comparable to the continued-influence studies discussed earlier; Ecker et al., in press; Wilkes & Leatherbarrow, 1988).

The prediction of a facilitative reminder effect is, however, at odds with interference theories of memory, such as temporal distinctiveness theory, which assume that items encoded in temporal proximity to to-be-remembered items will impair retrieval of target items (e.g., Brown, Neath, & Chater, 2007). In general, interference theories predict that reminders should impair memory for updated items, as the reminders would be an additional source of proactive interference (e.g., M. C. Anderson & Neely, 1996).

Experiment 1

Method

Experiment 1 involved study of two consecutive lists of items, each comprising 100 word pairs (e.g., *book-door*). After study of list 1, participants were informed that the list was in fact irrelevant for the later memory test, and they were explicitly instructed to update their memory for the first list by studying a second list of word pairs. The first word of each pair in list 2 was identical to the first word of each pair in list 1; however, in half the cases, the second word changed. Thus, half the list-2 word pairs were identical to list 1 (e.g., *book-door*); half were updates involving the substitution of the second word in the pair (e.g., *book-window*). Immediately before presentation of each list-2 word pair, a reminder of the associated list-1 pair was either provided or not; the reminder was the first word of the pair (e.g., *book*). The experiment thus used a 2 × 2 within-subjects design with factors substitution (no-substitution, substitution) and reminder (no-reminder, reminder). Note that no-substitution word pairs were presented twice across lists and did not require any memory updating; this condition acted as a control condition and was included with the sole purpose of preventing participants from using the reminder as a cue to remove outdated information (i.e., the second word of the list-1 pair) from memory before receiving the list-2 word pair (see Ecker, Lewandowsky, & Oberauer, 2014). Memory for list-2 word pairs was tested with an associative recognition test.

Reconsolidation theory predicted that a reminder would facilitate updating and would hence lead to superior memory performance (i.e., higher accuracy or quicker response times) for items in the substitution condition. We made no strong predictions regarding performance in the no-substitution condition; to the extent that a reminder might serve as a third encoding, a reminder could have a positive effect; to the extent that a reminder might be encoded as a stand-alone distractor item, the reminder could have a negative effect, or it could have no effect at all. Generally, higher performance was expected for word pairs in the no-substitution condition as compared to the substitution condition, because of the repeated encoding and the absence of confusable distractor items.

Participants. An a-priori power analysis suggested that detecting a small to medium-size effect of effect size $f = .15$ at $\alpha = .05$ and $1\text{-}\beta = .80$, with a moderate correlation between repeated measures ($\rho = .6$) required a sample size of $N = 50$. Accordingly, 53 undergraduate psychology students from the University of Western Australia participated in the study for course credit. The mean age was $M = 21.15$ years ($SD = 7.60$), with a range of 17 to 53[1]. The sample comprised 25 males and 28 females. Informed consent was obtained.

Apparatus. All tasks were completed on a standard thin-film-transistor computer screen using MATLAB.

Materials. For each participant, word pairs were constructed ad-hoc by randomly pairing words taken from the online version of the MRC psycholinguistic database (http://websites.psychology.uwa.edu.au/school/MRCDatabase/uwa_mrc.htm). The word pool comprised 270 nouns of three syllables or less, with a moderately high word frequency, as indicated by Kucera-Francis frequencies of 110 (e.g., ‘ball’) – 3,292 (e.g., ‘one’). Words with very low concreteness and imaginability ratings were excluded (words falling in the bottom 15% of the respective distribution).

Procedure. Each word pair was presented side-by-side in black lower case letters on a white background in the centre of the screen. Presentation time was 5 seconds per pair, with a 500 ms inter-stimulus interval. Participants were instructed to read each word pair aloud and were told their utterances were being recorded (a sham microphone was set up), in order to ensure adequate encoding. They were asked to remember as many word pairs as possible.

[1] The sample happened to include three age outliers (mature-age students aged 40, 46, and 53 years). Excluding these participants from the analyses did not affect results.

During presentation of the second list, half the list-2 word pairs were preceded by a reminder (i.e., the first word of the to-be-updated pair) presented in red for 750 ms (with a 500 ms reminder-stimulus interval). Participants were instructed to try and remember the associate to the reminder word from list-1, but not to say this pair aloud. Between the first and second list, as well as between the second list and the recognition test, there was a 1-minute tone-detection distractor task. Finally, a 160-item recognition test was administered, targeting list-2 word pairs. It consisted of 80 to-be-endorsed word pairs (old pairs from list-2, 20 per experimental condition) and 80 to-be-rejected word pairs (comprising 40 outdated list-1 word pairs, 30 recombined pairs of studied words from either list 1 or list 2, and 10 pairs of novel words). Participants were to press the ‘Z’ key for old (to-be-endorsed) pairs and the ‘/’ key for new (to-be-rejected) pairs, with a maximum response time of 5 seconds. Accuracy and response times were recorded.

Results

In the following, given the theoretical relevance of either the presence or absence of a reminder effect, we report traditional frequentists analyses augmented by Bayesian model-comparison analyses, which can also provide evidence *in favour* of the null (these were computed using the “Bayesian repeated measures ANOVA” module of JASP 0.8.0.0).

Accuracy. Raw accuracy scores were transformed into corrected recognition scores (*Pr* = hit rate – false alarm rate) for all four conditions. Participants were excluded from subsequent analyses if their overall *Pr* score was not reliably above chance-level (*Pr* = .11), as determined by a binomial test (with $\alpha = .10$). Ten cases were removed, leaving a sample of $n = 43$ participants. Mean *Pr* scores in the no-substitution/no-reminder (S-R-), no-substitution/reminder (S-R+), substitution/no-reminder (S+R-), and substitution/reminder (S+R+) conditions were $M_{\text{S-R-}} = 0.43$ ($SE = 0.03$), $M_{\text{S-R+}} = 0.46$ ($SE = 0.03$), $M_{\text{S+R-}} = 0.28$ ($SE = 0.03$), and $M_{\text{S+R+}} = 0.28$ ($SE = 0.03$), respectively.

A 2 × 2 repeated measures ANOVA with factors substitution (no-substitution, substitution) and reminder (no-reminder, reminder) yielded a significant main effect of substitution, $F(1,42) = 68.94$, $MSE = .02$, $\eta^2_p = .62$, $p < .001$, indicating poorer recognition for substituted word pairs. There was no significant main effect of reminder, $F(1,42) = 1.95$, $MSE = .01$, $\eta^2_p = .04$, $p = .17$, and no significant interaction, $F < 1$. A Bayesian analysis confirmed that evidence for a model including the substitution factor was strong ($BF_{10} = 1.28 \times 10^{14}$), whereas evidence regarding the additional inclusion of the reminder factor was indeed in favour of the null ($BF_{01} = 3.73$).

A closer analysis of responses to lures, contrasting performance across the three item categories (outdated list-1 word pairs, recombined pairs, and novel pairs) revealed a main effect of item category, $F(2,84) = 216.72$, $MSE = .02$, $\eta^2_p = .84$, $p < .001$. Novel item pairs ($M = .97$, $SE = .01$), and also recombinations ($M = .84$, $SE = .02$), were rejected with relative ease, whereas outdated list-1 pairs were often mistakenly accepted ($M = .61$, $SE = .02$). A Bayesian analysis also found strong evidence for an item category effect, $BF_{10} = 4.54 \times 10^{34}$.

Reaction times. Mean hit RTs were $M_{S\text{-}R\text{-}} = 1{,}182$ ms ($SE = 30$), $M_{S\text{-}R+} = 1{,}208$ ms ($SE = 41$), $M_{S+R\text{-}} = 1{,}312$ ms ($SE = 46$), and $M_{S+R+} = 1{,}335$ ms ($SE = 50$). A 2 × 2 repeated measures ANOVA with factors substitution and reminder yielded a significant main effect of substitution, $F(1,42) = 21.63$, $MSE = .03$, $\eta^2_p = .34$, $p < .001$, but no effect of reminder, $F(1,42) = 1.12$, $MSE = .02$, $\eta^2_p = .03$, $p = .30$, and no interaction, $F < 1$. The Bayesian analysis yielded solid evidence for inclusion of the substitution factor ($BF_{10} = 89{,}962$) and evidence against the additional inclusion of the reminder factor ($BF_{01} = 3.58$).

Discussion

Experiment 1 investigated memory for a list of word pairs (e.g., *book-window*), some of which had been studied previously (i.e., word pairs in the no-substitution condition), and some of which were updates of previously studied word pairs (i.e., word pairs in the substitution condition, e.g., *book-door*). The experiment tested whether a reminder of a previously learned word pair (e.g., *book*) would facilitate the subsequent memory updating of the word pair, thus leading to better memory for updated word pairs when preceded by a reminder, relative to a no-reminder condition. The experiment found superior memory for non-updated word pairs, which demonstrates that memory updating is not a trivial task (Ecker et al., 2010); this effect is easily explained by the repeated encoding of the pairs (e.g., Verkoeijen, Rikers, & Schmidt, 2004) as well as the absence of competing memory representations of outdated distractor pairs sharing the same first word (i.e., a fan effect; e.g., Schneider & J. R. Anderson, 2012). The importance of competing representations is further supported by the observed elevated rate of false alarms to outdated list-1 item pairs. The experiment found no effect of a reminder, and thus no evidence of reminder-induced facilitation of memory updating. Experiment 2 was run to replicate this finding with shorter study lists.

Experiment 2

Method

Experiment 2 was a direct replication of Experiment 1, but study and test lists were shortened to 40% of the length used in Experiment 1 (i.e., study lists with 40 word pairs, and a recognition test with 64 test pairs).

Participants. Due to the shortening of the task, we increased the number of participants to $N = 101$. Participants were undergraduate psychology students from the University of Western Australia, who participated for course credit. The mean age was $M = 19.12$ years ($SD = 2.80$), with a range of 16 to 31. The sample comprised 43 males and 58 females. Informed consent was obtained. One participant was removed from all analyses because they used a pen during the experiment.

Apparatus, materials, and procedure. Except for the shortening of lists, the experiment was identical to Experiment 1.

Results

Accuracy. As in Experiment 1, participants were excluded from subsequent analyses if their overall *Pr* score was not reliably above chance-level (*Pr* = .19), as determined by a binomial test ($\alpha = .10$). Thirty-three cases were removed, leaving a sample of $n = 67$ participants. Mean *Pr* scores were $M_{S\text{-}R\text{-}} = 0.49$ ($SE = 0.02$), $M_{S\text{-}R+} = 0.49$ ($SE = 0.02$), $M_{S+R\text{-}} = 0.11$ ($SE = 0.02$), and $M_{S+R+} = 0.07$ ($SE = 0.03$).

A 2 × 2 repeated measures ANOVA with factors substitution and reminder yielded a significant main effect of substitution, $F(1,66) = 198.89$, $MSE = .05$, $\eta^2_p = .75$, $p < .001$, indicating poorer recognition for substituted word pairs. There was no significant main effect of reminder, and no interaction, *F*s < 1. A Bayesian analysis confirmed that the evidence for inclusion of the substitution factor was strong ($BF_{10} = 4.58 \times 10^{45}$) and that evidence for the additional inclusion of the reminder factor was in favour of the null ($BF_{01} = 6.11$).

Analysis of lure responses across item categories (outdated, recombined, novel) showed an effect of item category, $F(2,132) = 229.25$, $MSE = .02$, $\eta^2_p = .78$, $p < .001$. Novel item pairs ($M = .98$, $SE = .01$), and also recombinations ($M = .86$, $SE = .02$), were rejected with relative ease, whereas for outdated list-1 pairs false alarms outweighed correct rejections ($M = .43$, $SE = .02$). A Bayesian analysis also found very strong evidence for an item category effect, $BF_{10} = 1.15 \times 10^{53}$.

Reaction times. Mean hit RTs were $M_{S\text{-}R\text{-}} = 1{,}266$ ms ($SE = 39$), $M_{S\text{-}R+} = 1{,}321$ ms ($SE = 51$), $M_{S+R\text{-}} = 1{,}441$ ms ($SE = 67$), and $M_{S+R+} = 1{,}507$ ms ($SE = 65$). A 2 × 2 repeated measures ANOVA with factors substitution and reminder yielded a significant main effect of substitution, $F(1,66) = 17.40$, $MSE = .13$, $\eta^2_p = .21$, $p < .001$, as well as a main effect of reminder, $F(1,66) = 4.41$, $MSE = .06$, $\eta^2_p = .06$, $p = .04$, indicating slower responses in the substitution and reminder conditions. There was no interaction, $F < 1$. The Bayesian analysis yielded strong evidence in favour of including the substitution factor ($BF_{10} = 7{,}602$). However, it yielded weak evidence *against* the additional inclusion of the reminder factor ($BF_{01} = 2.06$).

Post-hoc analyses. An obvious problem in Experiment 2 was the low average performance level. The reasons for this are not entirely clear, in particular because Experiment 2 was shorter than Experiment 1. Unlike Experiment 1, Experiment 2 was run at the end of a 1-hour experimental session. Thus, fatigue and motivation might be responsible for the low performance. Also, the analysis of lure responses showed that compared to Experiment 1, the false-alarm rate to outdated list-1 pairs was elevated even further in Experiment 2, thus reducing overall *Pr*, and suggesting that with a smaller number of study items, participants may have encoded stronger representations of list-1 items. Given the large number of available participants, it was decided to run a set of post-hoc analyses on the top half of participants of the original analysis of Experiment 2 (i.e., the best-performing participants based on overall *Pr*), in order to corroborate our findings.

With a sample of $n = 34$ participants, mean *Pr* scores were $M_{S-R-} = 0.84$ ($SE = 0.03$), $M_{S-R+} = 0.88$ ($SE = 0.03$), $M_{S+R-} = 0.48$ ($SE = 0.04$), and $M_{S+R+} = 0.45$ ($SE = 0.04$). A 2 × 2 repeated measures ANOVA with factors substitution and reminder yielded a significant main effect of substitution, $F(1,33) = 97.83$, $MSE = .05$, $\eta^2_p = .75$, $p < .001$. There was no main effect of reminder ($F < 1$), and no interaction, $F(1,33) = 1.13$, $MSE = .03$, $\eta^2_p = .03$, $p = .30$. The Bayesian analysis yielded strong evidence for inclusion of the substitution factor ($BF_{10} = 1.90 \times 10^{21}$) and evidence against inclusion of the reminder factor ($BF_{01} = 5.72$).

Mean hit RTs in the restricted sample were $M_{S-R-} = 1{,}217$ ms ($SE = 42$), $M_{S-R+} = 1{,}333$ ms ($SE = 66$), $M_{S+R-} = 1{,}405$ ms ($SE = 70$), and $M_{S+R+} = 1{,}508$ ms ($SE = 89$). A 2 × 2 repeated measures ANOVA with factors substitution and reminder yielded a significant main effect of substitution, $F(1,33) = 9.67$, $MSE = .12$, $\eta^2_p = .23$, $p < .01$, as well as a main effect of reminder, $F(1,33) = 8.60$, $MSE = .05$, $\eta^2_p = .21$, $p < .01$. There was no interaction, $F < 1$. The Bayesian analysis yielded evidence for the inclusion of the substitution factor ($BF_{10} = 49.01$) and was also slightly in favour of additionally including the reminder factor ($BF_{10} = 1.63$).

Discussion

The large accuracy main effect of substitution demonstrated again that memory is improved with repeated encoding and the absence of competing distractor representations. Unlike Experiment 1, Experiment 2 also found some evidence for an effect of a reminder, in that a reminder presented before encoding of the second-list word pair was associated with somewhat slower retrieval of that word pair at test. This finding must be interpreted with caution given the weak statistical evidence for it, but it is important to note that it runs directly *counter* to the prediction of reconsolidation theory. Apparently, processing a reminder with the instruction to reactivate the word pair from the initial list did not facilitate updating of the word pair; instead, a reminder seemed to slow down memory access to the list-2 word pair. The negative reminder effect was comparable for word pairs that were repeatedly encoded (no-substitution word pairs) and word pairs that were updated (substitution word pairs), which suggests that the retrieval impairment derives from impeded access to the target word-pair representation conveyed by the encoding of the one-word reminder. In essence, we thus argue that the reminder itself was encoded as an additional memory item, imparting interference on the target word pair that was encoded in close temporal proximity. This is compatible with temporal distinctiveness and interference theories of forgetting (Brown et al., 2007; Verde, 2004).

A complementary alternative view is that the reminder effect could itself be interpretable as a fan effect: in a paradigm involving study of word pairs, the absence of an associate word may itself have been a memorable context feature of the word’s presentation.

Thus, a word used as a reminder may have been associated with two (no-substitution) or even three (substitution condition) "associates" (e.g., *book-door*, *book-window, book-*'*no word*'). It is well known that higher fan can lead to weaker associations and thus slower recognition responses (e.g., Schneider & J. R. Anderson, 2012).

General Discussion

In two experiments, we tested a prediction derived from reconsolidation theory, namely that reminders of previously learned word pairs would facilitate updating of those word pairs and thus later recognition of the updated word pairs. No such effect was found. If anything, our results indicated that reminders might even slow retrieval of updated information, in line with interference-based theories of memory. Thus, to the extent that our reminders were successful in reactivating the initial representations of word pairs, the present results argue against a role for reconsolidation in memory updating, at least on the time-scale of minutes.

However, while memory performance in the present study can be explained by constructs well-established in the cognitive science literature, present findings should not be taken to argue that reconsolidation in general is irrelevant for human episodic memory. This is because conclusions are hampered by confusion regarding the boundary conditions of potential reconsolidation effects in updating (cf. Nader & Hardt, 2009). In particular, the critical time parameters of reconsolidation have not been fully specified. It is thus possible that the present study did not meet the requirements of when and how reconsolidation is relevant—the present study allowed only a few minutes between the encoding of list 1 and the presentation of reminders, and this may not have been a long enough period of time for labilization to be required or beneficial for updating. While it has been claimed that reminders immediately trigger labilization (Chan & LaPaglia, 2013), and that a reminder labilizes a memory trace for up to six hours (e.g., Schiller et al., 2010), it remains unclear how much prior consolidation there must have been for labilization to facilitate updating of a memory trace. For example, while Chan and LaPaglia (2013) commendably varied all relevant time periods in their experiments systematically, they did not specify their standard delay after initial learning (although it should be noted that Ecker et al., in press, and Wilkes & Leatherbarrow, 1988, used short delays of a few minutes comparable to the delay in the present study). Thus, while we argue that the present study provides evidence against the relevance of reconsolidation for memory updating on short time-scales (i.e., minutes), it seems pertinent to further specify the time parameters of reconsolidation to facilitate further testing of theory-based predictions (cf. Ecker & Lewandowsky, 2012).

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